

## CLAIMS

1. A fuel injection control apparatus for an internal combustion engine equipped with a fuel injection valve for directly injecting high pressure fuel supplied by high pressure fuel supply means into a cylinder, comprising:

in-cylinder pressure detection means for detecting or estimating in-cylinder pressure of said cylinder;

time period calculation means for calculating fuel injection time period over which fuel is injected from said fuel injection valve, the fuel injection time period being corrected to compensate a variation in the fuel injection quantity caused by a variation in the fuel injection rate due to a variation in the in-cylinder pressure detected or estimated by said in-cylinder pressure detection means relative to a reference in-cylinder pressure that is stored in advance;

start time variation calculation means for calculating a variation in the fuel injection start time at the in-cylinder pressure detected or estimated by said in-cylinder pressure detection means relative to the fuel injection start time at said reference in-cylinder pressure;

control means for controlling the time period over which fuel is injected from said fuel injection valve based on the fuel injection time period calculated by said

time period calculation means and the variation in the fuel injection start time calculated by said start time variation calculation means.

5           2. A fuel injection control apparatus for an internal combustion engine according to claim 1, further comprising:

          fuel pressure detection means for detecting the pressure of the high pressure fuel supplied to said fuel  
10 injection valve by said high pressure fuel supply means;

          fuel injection quantity characteristic storing means for storing a characteristic, in relation to valve opening time of said fuel injection valve, of the fuel injection quantity injected by said fuel injection valve during the  
15 valve opening time in accordance with the pressure of the high pressure fuel supplied to said fuel injection valve by said high pressure fuel supply means;

          required fuel injection quantity calculation means for calculating a desired fuel injection quantity based on  
20 the running state of the internal combustion engine;

          fuel injection rate calculation means for calculating fuel injection rate based on the fuel pressure detected by said fuel pressure detection means and the in-cylinder pressure detected or estimated by said in-  
25 cylinder pressure detection means;

          fuel injection quantity variation calculation means for calculating a variation in the fuel injection quantity

caused by a variation in a second fuel injection rate  
calculated by said fuel injection rate calculation means  
based on the in-cylinder pressure detected or estimated by  
said in-cylinder pressure detection means relative to a  
5 first fuel injection rate calculated by said fuel  
injection rate calculation means based on said reference  
in-cylinder pressure;

coefficient calculation means for calculating a  
variation in fuel injection delay time per unit in-  
10 cylinder pressure for the fuel pressure detected by said  
fuel pressure detection means,

wherein, said time period calculation means  
calculates the fuel injection time period utilizing said  
fuel injection quantity characteristic storing means based  
15 on the variation in the fuel injection quantity calculated  
by said fuel injection quantity variation calculation  
means and the fuel injection quantity calculated by said  
required fuel injection quantity calculation means,

said start time variation calculation means  
20 calculates the variation in the fuel injection start time  
based on a variation in the in-cylinder pressure detected  
or estimated by said in-cylinder pressure detection means  
relative to said reference in-cylinder pressure and the  
variation calculated by said coefficient calculation means.

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3. A fuel injection control apparatus for an  
internal combustion engine according to claim 2, further

comprising:

a needle valve provided in said fuel injection valve that moves in the axial direction to effect valve opening and closing operations;

5           fuel injection quantity estimation means for estimating, when fuel injection by said fuel injection valve is started, the quantity of fuel injected since the valve opening operation of said needle valve is started until said needle valve reaches a full open state, based  
10       on the fuel pressure detected by said fuel pressure detection means and the in-cylinder pressure detected or estimated by said in-cylinder pressure detection means;

          comparison means for comparing the estimated fuel quantity estimated by said fuel injection quantity  
15       estimation means and the fuel injection quantity calculated by said required fuel injection quantity calculation means,

          wherein, said fuel injection quantity variation calculation means calculates the variation in the fuel  
20       injection quantity using different calculation processes, in accordance with a result of the comparison by said comparison means, between in the case that said fuel injection quantity is less than said estimated fuel  
25       quantity and in the case that said fuel injection quantity is more than or equal to said estimated fuel quantity.

4. A fuel injection control apparatus for an

internal combustion engine according to claim 2 or 3,  
wherein said fuel injection quantity variation calculation  
means calculates the variation in the fuel injection  
quantity by modeling a change with time in the fuel  
injection rate as a polygon in a coordinate system and  
calculating a change in the area of said polygon.

5. A fuel injection control apparatus for an  
internal combustion engine according to claim 3, wherein  
said fuel injection quantity variation calculation means  
further comprises:

suction chamber pressure calculation means for  
calculating pressure in a suction chamber formed in the  
tip end side of a valve seat on/from which said needle  
valve is to be received/detached, based on the fuel  
pressure detected by said fuel pressure detection means  
and the position of said needle valve;

unit fuel injection quantity variation calculation  
means for calculating a variation in the fuel injection  
quantity per unit in-cylinder pressure based on the fuel  
injection quantity calculated by said required fuel  
injection quantity calculation means and the suction  
chamber pressure calculated by said suction chamber  
pressure calculation means,

wherein, when according to a result of the  
comparison by said comparison means, said fuel injection  
quantity is less than said estimated fuel injection

quantity, said fuel injection quantity variation calculation means calculates the variation in the fuel injection quantity based on a variation in the in-cylinder pressure detected or estimated by said in-cylinder pressure detection means relative to said reference in-cylinder pressure and the variation in the fuel injection quantity per unit in-cylinder pressure calculated by said unit fuel injection quantity variation calculation means.

10           6. A fuel injection control apparatus for an internal combustion engine according to claim 1, further comprising:

          fuel pressure detection means for detecting the pressure of the high pressure fuel supplied to said fuel injection valve by said high pressure fuel supply means;

15           fuel injection quantity characteristic storing means for storing a characteristic, in relation to valve opening time of said fuel injection valve, of the fuel injection quantity injected by said fuel injection valve during the valve opening time in accordance with the pressure of the high pressure fuel supplied to said fuel injection valve by said high pressure fuel supply means;

20           required fuel injection quantity calculation means for calculating a desired fuel injection quantity based on the running state of the internal combustion engine;

25           first virtual fuel pressure calculation means for calculating a first virtual fuel pressure by subtracting a

variation in the in-cylinder pressure detected or  
estimated by said in-cylinder pressure detection means  
relative to said reference in-cylinder pressure from the  
fuel pressure detected by said fuel pressure detection  
5 means;

second virtual fuel pressure calculation means for  
calculating a second virtual fuel pressure by adding a  
variation in the in-cylinder pressure detected or  
estimated by said in-cylinder pressure detection means  
10 relative to said reference in-cylinder pressure to the  
fuel pressure detected by said fuel pressure detection  
means;

injection delay time calculation means for  
calculating injection delay time from the time at which a  
15 signal for opening said fuel injection valve is generated  
to the time at which fuel injection by said fuel injection  
valve is started, based on the fuel pressure detected by  
said fuel pressure detection means,

wherein, said time period calculation means  
20 calculates the fuel injection time period utilizing said  
fuel injection characteristic storing means based on the  
first virtual fuel pressure calculated by said first  
virtual fuel pressure calculation means and the fuel  
injection quantity calculated by said required fuel  
25 injection quantity calculation means, and

said start time variation calculation means  
calculates, by means of said fuel injection delay time

calculation means, a fuel injection delay time for the  
fuel pressure detected by said fuel pressure detection  
means and a fuel injection delay time for the second  
virtual fuel pressure calculated by said second virtual  
5 fuel pressure calculation means and calculates the  
variation in the fuel injection start time from a  
difference between those injection delay times.